SCIENCE

FRIDAY, JUNE 20, 1919

CONTENTS

MSS. intended for publication and books, etc., intended for review should be sent to The Editor of Science, Garrison-on-Hudson, N. Y.

THE AIRPLANE IN SURVEYING AND MAPPING

THE airplane, while not a product of the war, owes its present prominent place to the war, and but for the war its development would have been retarded many years. It had few practical uses from the time the Wright brothers first flew their machine at Fort Myer, Va., in 1909 until 1914. It was a plaything to amuse the holiday crowd.

The war changed this situation. The allies and the central powers almost immediately saw the great importance of the airplane in battle and the best brains and energy of the warring nations were given to the problem of making the airplane perform what a few years ago would have been considered miraculous things.

War planes were made for various purposes, which I need not enumerate. But the most important thing done from the airplane was photographing the enemies' lines to obtain many kinds of military information, such as positions of batteries and ammunition dumps, changes in trench systems, troop movements, etc.

The same methods, with some modifications, are now being considered in connection with the mapping of extensive areas by various organizations of this country. In fact, some work has already been done and experiments are being carried on which promise excellent results.

There is so much misinformation regarding surveys and maps, that it seems appropriate for me, as the head of the oldest map-making bureau of the government, to present the mapping situation to this congress, both for your information and as a matter of record.

Surveying and mapping have long histories and the development of the methods now employed took centuries. But the method of airplane surveying has developed like a mushroom. To what extent is it applicable to our needs? This I shall endeavor to show.

In collecting data for a map those surveying methods must be adopted in any particular case that suit the requirements. If one should wish only a route map running from one village to another, it would be perfectly satisfactory to use a compass for direction and the pacing of a horse or the readings of an odometer on a wheel for the distance between the two points. But maps are usually not so simple as that.

TYPES OF MAPS

There are several types of high grade maps needed in this country. One must be made along the coasts to show the location of the actual shore line and the character of the ground immediately back of the coast in order that the navigator may be able to locate himself from topographic features along the shore, should he be driven off his course during a storm. In addition the depths of the water and all obstructions to navigation must be indicated on this map or chart, and the elevation and shape of the ground on islands and near the shore line must be shown by contours.

A second class consists of maps on which the features other than elevations are shown in their correct horizontal positions. This type of map would be practically the same as the third type where the area covered is very level like the coastal plain of Louisiana.

The third class covers maps of the interior or of large islands on which all features, cultural and natural, are located in their proper horizontal positions and contours are shown to give the elevations of the ground and the shape of the hills, ridges, valleys, etc. This map would be used by engineers in laying out railroads and highways, and in conducting various classes of engineering work.

These three classes of maps are the ones in which we are most directly interested.

The map which shows the horizontal positions of cultural and natural features on the surface of the earth, but no contours, can be made more rapidly than the one which requires contouring. All that is needed in the former case is some method of obtaining the direction and distance between each two features in the area to be surveyed. The usual method of making such a map is by compass and chain, transit and tape, transit and stadia, or by the plane table. These methods are all very closely allied and such accuracy as may be demanded may be obtained by varying the methods used.

MAPS CONTROLLED BY FIXED POINTS

In any event there must be within the area to be surveyed, if it is a large one, a number of control stations. These control stations consist of triangulation stations placed on the highest parts of the ground or traverse stations along the roads, accurately located in latitude and longitude and accurately and substantially marked with concrete or rock in order that they may be recovered and identified by the surveyors or engineers who may wish to see them.

There are now many thousands of such stations in the United States, established principally by the Coast and Geodetic Survey, available for the fundamental control of surveys and maps. From these stations control of the same or of a lower grade of accuracy may be extended in any direction for the immediate control of topographic maps.

OVERLAPS, GAPS AND OFFSETS TO BE AVOIDED

It is readily seen that without the fundamental control, which extends over the whole area of the United States, there would be great confusion. If the control in any one state is not properly coordinated and correlated with that of any other state near it, the result will be that when different topographic surveys and maps are joined there will be overlaps, gaps and offsets which cause no end of trouble and confusion to the cartographer and map maker. When there is a single system of control for the whole country we avoid this unfortunate condition.

3,000,000 SQUARE MILES, LESS THAN ONE HALF MAPPED

There is to-day only about 40 per cent. of the 3,000,000 square miles of the United States mapped both as to horizontal positions of the

features and the elevations by contours of hills, ridges, valleys, etc. These are the maps of class three, mentioned previously. Some of the 40 per cent. of the surveyed area will have to be resurveyed because the original work was done many years ago when methods were not as refined as they are at present and the demands of map users were not as exacting as they are to-day. It is safe to say that not over 30 or 35 per cent., or one third of the whole country is adequately mapped.

The question is, what shall be done with the other 60 per cent. This is a question that is puzzling map makers constantly and no ready solution is at hand provided we insist on having a map of the whole area within a few years.

It is possible that here may be a valuable field for the airplane. It is not believed that the airplane unsupported by other surveying can give the final accuracy required in original survey. But by its means a map can be made that will be much better than the maps which may be in existence to-day in the areas not topographically mapped. In order that the remaining 60 per cent. of the country might be mapped by airplane it would be necessary to have a great amount of triangulation and traverse run with a view to furnishing the horizontal control for the photographs to be made by the airplane. With this control, it would be possible to fit the photographs on the map into their proper positions.

AIRPLANE SURVEYING WILL DEVELOP

It is not possible to run many miles with airplane photographs and expect a very high degree of accuracy in the resulting maps. And here I wish to give a word of caution to the advocates of airplane mapping. Too much must not be expected of it. The development of this science will undoubtedly be rather slow for a few years. After it has been developed the methods must, of course, be thoroughly tested before they can be adopted. It is well that this is so, for otherwise haste might cause mistakes which would discredit the method to such an extent that it would take years to recover.

CHARTS OF THE COAST

The first class of maps considered here consists of charts of the Coast and Geodetic Survey which show the level area immediately along the coast and the water area for some distance out from the shore. The purpose of coast charting is to furnish a safe means of communication by vessels along the coast or in approaching the coast. At present, the methods employed are the usual ones for the topographic surveying of the shore line and the area immediately back of it and the ordinary hydrographic methods for the surveying in the water.

Although the coast line of the United States has been mapped, yet the currents and waves of the oceans cause many large changes in this shore line. For instance Fire Island entrance, Long Island, New York, was changed in position about four miles in fifty years. The changes are so rapid that frequent resurveys of the coast must be made to furnish exact and reliable information to the navigator. It is also necessary to revise the area just back from the coast, for roads are frequently changed in position or abandoned, new ones are established, houses are built or burned, villages spring up, woods are removed or grow over what were vacant fields at the time the map was made, and all of these changes should be shown for the use of the mariner. The question arises as to how such revision shall be made.

REVISION OF CHARTS BY AIRPLANES

From the experience of the engineers of the Coast and Geodetic Survey the revision of an area that does not need contouring is almost as expensive and takes almost as much time as the original survey, for it is necessary to make a test of the position of each feature. It is here that the airplane will be of the greatest service, for if a portion of the shore line needs to be inspected with a view to learning whether or not the map of it should be revised, we could have a series of photographs made by an airplane along the coast, and a comparison of these photographs with the original map would enable one to locate very defi-

nitely each area within which there are new features or where old ones have changed. It is doubtless true that in such cases the details of an airplane photograph could be placed on the map from the photograph with all of the accuracy that is needed in the topography shown on the coast charts.

It is a debatable question as to whether the airplane photograph made over a water area will show any outline of submerged dangers to navigation when the plates are developed. If they do there is a vast field for the airplane in making photographs over water areas where it is known that many obstructions exist. With the usual surveying methods, it is difficult at times to locate every obstruction. One or more on any chart might be missed. This fact has been proved a number of times in a most disastrous way by vessels running on uncharted rocks both along our eastern and our western coasts and especially in Alaska.

The Coast and Geodetic Survey is now making wire drag surveys of all doubtful areas along the coast, but it will be many years before the bureau can assure the navigating public that all obstructions have been found and accurately charted.

AIRPLANES AND HYDROGRAPHIC SURVEYS

It may be possible that an airplane photograph will indicate submerged rocks or other dangers that are close to the surface of the water. It would be a question of differences in shade in the photograph. If such a detection of danger can be made then it will be necessary to make the photographs only on perfectly clear days. Otherwise, the shadow on the water of a passing cloud might show on the photograph and cause uncertainty as to whether the spot was a cloud or an actual obstruction.

There are many hundreds of square miles of area along the coast that consist of salt marshes with many streams of little or no importance, but which should be shown in their proper relation to other topographic features. These marshes can be photographed from airplanes and the streams running through them would probably show in such a way that they could be fitted into the map from the photograph. Here might be a large saving of time for the surveyor in the field.

There are other cases where there are extensive mud flats, when the tide is low, as in Jamaica Bay, New York. To survey the outline for these flats is rather laborious, with the usual instrumental methods, but it is believed that it might be possible to photograph them from an airplane and have the results placed on charts. It will undoubtedly be possible to get these located on the charts from airplane photographs with all the accuracy that is necessary for the navigator.

LOCATION OF DANGERS TO NAVIGATION

In making photographs from the water, for the purpose of discovering obstructions to navigation at low tide it will be necessary to have some means to properly locate photographic features on the chart. This probably can be done by anchoring two or three small boats within the area of the photograph and locating them with relation to triangulation stations. The location could be done in the usual way in which the sounding boat is today given its position, that is by taking two sextant angles simultaneously from the boat to three control points. It can readily be seen that if two or three accurately located boats are clearly shown on the aeroplane photograph, it will be possible to place the topographic details on the map in their proper positions.

I do not wish to convey the idea that the airplane photography will supersede the usual methods of hydrographic surveying, but it would supplement those methods by making it possible to discover channels running through mud flats, also coral heads, shoals, and other obstructions which might be close to the surface of the water and which may be missed by the usual methods of conducting hydrographic surveying.

There has been a rather positive statement made above that the airplane can be used to advantage in the work of the Coast and Geodetic Survey. This is undoubtedly true, but only time and the development of the methods

can show just how much the airplane can be used by this bureau.

THE AIRPLANE IN TOPOGRAPHIC MAPPING

We come now to the third class of maps and that is a subject on which I hesitate to express an opinion. That is the mapping of the interior of the country. This work is undertaken by the U. S. Geological Survey, supplemented to a certain extent by the Corps of Engineers, U. S. Army. The Coast and Geodetic Survey cooperates with those two organizations to the extent of furnishing the fundamental horizontal and vertical control for the surveys and maps, but almost all of the actual location of artificial or natural features is done by the other organizations. It is understood that the officers of those two organizations have given consideration to the question of map-making by airplane photographs. It is hoped that airplane surveying can be developed at least to supplement the usual surveyor's methods in mapping the interior on a comparatively large scale map with high accuracy.

It would appear that if the airplane photograph will be of so much assistance in the topographic work along the shores of the country that it would really be of some value in the interior.

Whether or not it is possible to locate contours from airplane photographs is a question that has not yet been decided. Many persons who have studied the question claim that it is impossible to locate contours accurately from airplane photographs. Others claim that they can be located with great accuracy. The substance of the situation is probably this: it will be possible later to devise methods of contouring from photographs provided that we can solve one or two of our present more fundamental problems. It is possible that the stereoscopic method can be applied to two photographs taken by two cameras on the same airplane or by cameras on two different airplanes together to obtain a rough idea of the configuration of the country.

SURVEYING THE INTERIOR OF THE COUNTRY

With regard to surveying the interior of the country for the purpose of making an accurate large scale, contoured map, I may say that here the airplane photographs can undoubtedly supplement the usual surveying methods, but can not entirely supplant them.

Such a map should probably be on a 1/50,000 scale, that is one foot on the map would equal 50,000 feet on the ground, and the distance between control points on the opposite edges of the area of a map should be correct within about 1 part in 10,000. The only method by which this can be accomplished is by triangulation and transit and tape traverse. The method to-day is to establish the triangulation and traverse stations ahead of the topographic surveying, with the geographic positions, that is latitudes and longitudes computed on the North American or final datum. When the control points are placed on that datum their positions will not have to be changed when two maps are joined.

The control, namely triangulation and traverse, bears the same relation to the topographic mapping of the country that the steel framework of a sky-scraper bears to the detailed portions of the building, such as walls, floors, doors, windows, etc. If the steel work is not accurately fastened and adjusted when erected, before the detailed portions are started on a building, it is reasonably certain that the building will be distorted in shape and will be structurally weak.

The same idea pertains to maps, and the difficulty mentioned actually exists to-day in some parts of our country, where the detailed mapping of certain areas had to precede the triangulation and traverse based on the North American datum. The result has been overlaps, gaps, offsets, etc., when two maps, based on different data have been joined together.

LATITUDES, LONGITUDES AND ELEVATIONS NEEDED

It is the province of the Coast and Geodetic Survey to extend the fundamental control, that is, latitudes and longitudes in long arcs throughout the country. These arcs are interlaced in order that the requisite strength may be obtained. This work has been carried on as vigorously as the funds at the disposal of the Survey would permit. We have arrived at a situation to-day which demands that this work be expedited, and it is hoped that Con-

gress will respond to our appeals for funds in order that the work may be carried on so rapidly that all mapping operations of federal, state, city, county and private organizations, may have their needs met. This is a very urgent matter and I shall do my utmost to persuade the authorities to give this branch of federal surveying ample support, in order that the country may be mapped more satisfactorily and more efficiently.

When this control is available in any area, the usual method is to have surveying parties in the field place the topographic features on the maps in their proper relation to the control points. Every object on the face of the earth has one, and only one position, and it is the duty of the surveyor to place that object, whether it is a road crossing, a bridge, the top of a hill, or any other object, in its proper position on the map. On the most exact map for military purposes a well-defined feature is placed on the map within thirty feet of its exact relation to the nearest control station. Other maps have larger allowable discrepancies.

The work involved in the topographic surveying consists not only in placing the features on the map in their correct horizontal positions, but also in showing by contours the lines of equal elevation, the slopes of the ground, the shapes of hills and the exact elevations of a number of critical points.

The elevations are based upon lines of levels run inward from the oceans. The surface of the ocean, if it were at rest, would be a continuous one, and thus the mean position of the surface serves as a datum plane from which to measure heights in the interior of the country. More than 40,000 miles of the highest grade leveling has already been established in the interior of the country, and there are more than 20,000 precise leveling bench marks whose elevations are known within a very small portion of a foot.

In addition to the above there are many thousands of miles of leveling of a lower grade of accuracy which is used for the immediate control of the topographic surveying.

It is the duty of the Coast and Geodetic Survey to extend the lines of precise leveling into the interior of the country for the purpose of furnishing starting points for the leveling needed for the immediate use of the surveyor and engineer. What has been said in regard to the fundamental horizontal control is also applicable to the precise leveling. Many more thousands of miles of this grade of leveling are needed in the United States to-day and it is hoped that the bureau may be given the support necessary to complete within the next few years the work which is now needed and should have already been done.

TOPOGRAPHIC SURVEYING WITH PLANE TABLE

The topographic surveying is done generally by means of the plane table which consists of a tripod with certain fixtures and a plane board mounted thereon. The board is approximately 24×30 inches in horizontal dimensions. On this board is placed a sheet of paper on which the topographical features are shown. On the paper there will have been placed before going to the field, the positions of the control points, and with these as starting points, the topographer weaves a net showing the various features of the earth's surface by means of symbols. These symbols have been standardized by the map users of the United States. Any one wishing to utilize the information given by one of the high-grade maps, should be thoroughly familiar with these symbols.

As far as present development of airplane photography is concerned, it seems absolutely necessary in making the contoured survey, to do the work with the present methods. One can readily understand that it would be impossible to show contours at intervals of twenty feet over a wooded area, where trees in different parts of the forest varied in height. The area photographed will not show the differences of elevations of trees in a wood, for the low trees and bushes not more than twenty feet in height, would show about the same on a photograph as a primitive forest where the trees may be seventy to one hundred feet high.

ENGINEERS NEED ACCURATE MAPS

The contoured map must be of such accuracy as to enable the highway engineers, and engineers engaged on irrigation projects, to lay out their work accurately. It can be readily seen that with an accurately contoured map, the engineer can plan the railway, the highway, etc., from one place to another, and not make great mistakes in grades and alignment. It is doubtful if, even after considerable research work, airplane photography would ever produce a map contoured accurately enough for such engineering work. It is of course possible that some method may be discovered by which the differences in elevation between two points shown on each of two separate photographs can be computed, but if one considers that the work involved, if it can be done at all, will be very great, he will see that it will probably be more economical to put the contours on the map by the usual methods, than to compute innumerable elevations from photographs.

The possible method of computing distances and elevations from photographs may be supplemented by using the stereoscopic method which would give one an idea of the configuration of the ground. This would enable the draftsman in the office to select critical points whose elevations could be determined. Such critical points would be crests of hills or ridges and the bottoms of slopes. If the elevations of critical points are determined then contours could be interpolated between them.

I am giving these statements with a good deal of reservation on my part, for the method of contouring by airplane photography has not been developed and it may be that very little can be accomplished where accurate contouring is desired. Investigation has not yet been carried to the point where one can state definitely the possibility or impossibility of contouring by this method.

AIRPLANE SUPPLEMENTS PLANE TABLE

But this accurate large-scale contoured map can undoubtedly be made by combining the usual methods of surveying with the aero-photographs. The aero-photographs will usually give a great deal of detail which may facilitate the progress of the map by the topographer using the plane table. It will be necessary of course for the topographer to select a number of definite points on his map, such as road crossings, large buildings, groups of buildings, bridges and other features which can be identified from the photographs. Those features would serve as control points for the topographic details shown on the photographs. Without such points located by the usual methods, it would be necessary to place certain conspicuous objects on the ground near the triangulation and traverse stations. Almost any kind of object that would show in the photograph, and have a distinct shape, could be used. But the placing of these objects would be expensive. It is believed that the location of the conspicuous features referred to above could be done by the topographer at a much smaller cost than the cost of placing objects for the aero-photographs, at the triangulation and traverse stations.

It is possible that the topographer would be able to place the topographic details on his map from the photographs before going into the field to do the contouring. Much of the work of the topographer by the usual methods consists in placing the topographic features on the map in their proper location, but a great deal of this might be obviated by the use of the photographs. Then he could go into the field and place the contours with greater rapidity than if he attempted to do so previous to using the details of the photographs.

AIRPLANE VALUABLE FOR MAP REVISION

What I have stated above in regard to original surveys by aero-photography, in the three classes of high-grade maps, are simply opinions or prophesies. These are the coast charts, the contoured maps of the interior, and maps which show all features except contours, but I feel confident in stating that even on the highest grade of topographic maps, the aero-photographs can be used to a great degree in revising and bringing up to date maps of that character which have already been made. Let us suppose that we have be-

fore us a topographic map made by the U. S. Geological Survey, say ten years ago, and let it be supposed that this map, at the time it was made, was absolutely perfect. The map is supposed to show the contours, woods, streams, houses and other features that are usually represented on such a map. In the ten years since the map was made, it is reasonably certain that some changes have been made by the works of man. It is improbable that natural features would have changed, such as streams, woods and hills, during such a short period. We may assume that new roads have been made, old buildings torn down, or burned, and new ones erected, that wooded areas have been cleared, and that brush or young trees may now be on areas that were bare at the time the original survey was made. In order to test such a map and learn whether it was up to date, it would be necessary by the usual methods, to send a surveyor into the field to go over the area in great detail. Of course an inspection could be made of an area by driving over it, but many changes might be overlooked by this method of inspection.

How much simpler and more reliable it would be to send an airplane over the area in question and make a series of photographs. These photographs would show at a glance, the exact areas where changes in the features had occurred, and if the changes were not too complicated it is probable that we would be able to place the new features on the map directly from the photographs. The process would be to fit in the new features between unchanged old features, which of course would also be shown on the photographs.

PHOTOGRAPHIC PLATE SHOULD BE HORIZONTAL

In what has been said above, it has been assumed that the photographs have been made with the camera vertical, or, in other words, with the photographic film or plate in a horizontal position. It is only in this way that absolutely accurate photographs could be made. If the camera is tilted from the vertical at the instant the exposure is made, then there will be a distortion of the photograph so far as the map is concerned. If this tilting were known, then the photograph could be rectified and the features shown on the map with the same accuracy as if the plate had been horizontal at the time of the exposure.

It is hoped that methods will be developed for holding the camera in a vertical position at the time of exposure. I know of none now in use which is entirely satisfactory.

CONCLUSION

I may conclude that airplane surveying can be done now and it undoubtedly has a bright future. Much experimentation must be done, however, before the airplane can be used extensively in high-grade work.

I feel that the airplane can now furnish maps of a low order of accuracy so far as scale and position of features are concerned, which will be of considerable value in many branches of industry and commerce. They will undoubtedly be extensively used in unmapped areas in this and other countries in the very near future, for reconnoissance surveys and maps. But I hope they may be of great use in more accurate work.

I can pledge the Coast and Geodetic Survey, so far as its limited resources will allow, to take its part in making such tests by airplane as may be feasible in connection with surveying and mapping.

E. Lester Jones
U. S. Coast and Geodetic Survey

TRAINING IN SUGAR TECHNOLOGY IN HAWAII

Hawaii leads the world in her applications of science to the production of cane sugar. In no other country is the cultivation of cane so highly developed, the extraction so high, the chemical control so thorough, the mill processes so accurately coordinated. The entire organization of Hawaii's sugar industry is unparalleled for business efficiency and scientific control.

The experiment station of the Hawaiian Sugar Planters' Association is recognized throughout the world for the high quality of its investigational work. Its resources are